RARE EARTH ELEMENT ANALYSIS BY SXRF OF TWO RYUGU ROCK FRAGMENTS COLLECTED DURING THE HAYABUSA2 SPACE MISSION

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Introduction: The samples collected from the surface and subsurface regions of Cb-type Asteroid Ryugu by the Hayabusa2 sample return mission provide a unique opportunity to identify and quantify the presence of rare earth elements (REE) within minerals of pristine and primitive carbonaceous material with no terrestrial influence from atmospheric entry and deceleration nor from terrestrial weathering. The surface of the dark, rubble-pile asteroid Ryugu is reported to contain widespread hydrous minerals [e.g. 1], attesting to the occurrence of widespread aqueous alteration. High resolution (HR) synchrotron X-ray fluorescence (SXRF) spectroscopy was applied at the ID15A beamline at the ESRF – The European Synchrotron in Grenoble, France [2,3] to identify the REE-bearing minerals, map their spatial distribution, quantify their individual REE-concentrations and compare these with the REE concentrations of the Ryugu matrix and those of CI bulk values [4]. We report the results of SXRF analysis of two mm-sized Ryugu fragments: A0055 and C0076.

Methods: Both rock fragments were analysed as full fragments in non-air-exposed condition, enclosed within a polyimide cap with oxygen free atmosphere and no further sample preparation was performed in any way. A high-energy (90 keV) incident beam was applied to investigate elements in the range of $20<Z<73$. The emitted fluorescence radiation was detected by two detectors (one with Ge-sensor and one with Si-sensor) positioned at 180° to each other, one on either side of the sample and both orthogonal to the incident beam. The beam size was 0.5 µm x 0.5 µm and scans were performed at steps of 5 µm (overview scans) and 1 µm (HR scans). Cross-sectional scans were performed with 360° rotation of the sample at rotational steps of 0.4°. Point analyses were performed on selected grains with an acquisition time of 600 s per point [5].

Results: The main REE-bearing mineral is apatite, present as single grains (<10 µm) or clusters. Two apatite grains contain REE concentrations that vary between 40 – 100 times CI REE abundances and one apatite grain shows noticeably higher REE concentrations at about 250-300 times CI abundances. The REE patterns for the apatite grains measured in A0055 and A0076 may suggest a small positive Gd anomaly or no Gd anomaly. REE concentrations in dolomite are 3-10 times bulk CI REE values and show a slight increasing trend between La and Dy, after which no heavier REE was detected. REE concentrations in the measured matrix points vary between 0.10 – 10 times bulk CI REE values and include Eu-anomalies which differ in direction between the two analysed Ryugu rock fragments, with the A0055 matrix point showing a negative and the three C0076 matrix points a positive Eu anomaly.

Conclusion: The REE results for apatite, dolomite and matrix show a noticeable variation between grains and between the two samples. Further work will investigate whether this variation can be associated with regional differences, such as brecciation or the proximity to other minerals or structures, and will provide further insight into the process of aqueous alteration experienced on the dark, rubble-pile asteroid Ryugu.

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